

Session M – Mechanical Engineering/Aeronautics (Alphabetical)

Computational Fluid Dynamics and Thermal Analysis of a Titan Montgolfiere

Aditya Bhujle

Mentor: Tim Colonius

Saturn's largest moon, Titan is of great scientific interest as its atmosphere includes organic compounds which lead scientists to believe that the moon may be like a frozen vault of conditions similar to those on Earth before life began. Montgolfieres have been incorporated into several exploratory mission concepts over the last two decades, and have been identified as ideal lighter-than-air vehicles for a mission to Titan. Using a fast immersed boundary fractional step algorithm, we can compute and model laminar axisymmetric flows around and inside the Montgolfiere, and thus calculate the temperature distribution and analyze flow fields. In the past such computations have been performed for ideal cases. Realistic cases which deal with a hole at the bottom of a spherical balloon are considered and compared to the original cases without the hole. Also, altitude control by venting is approximated to a variation in the size of a hole at the top of the Montgolfiere. The buoyancy and velocity field variations as functions of the hole-size are analyzed for single walled and double walled Montgolfiere balloons.

Creating an Embedded System to Control the UCLA/Caltech Epidural Spinal Cord Implant

Anik Debnath

Mentor: Joel Burdick

In conjunction with the Yu-Chong Tai Group at Caltech and Professor Reggie Edgerton's group at UCLA, the Burdick Group has developed an epidural spinal cord implant that facilitates locomotion rehabilitation in subjects with severed spinal cords. The implant currently contains a grid of up to 32 electrodes. In order to fully realize the functionality of these implants, an embedded system must be developed that is capable of individually controlling all 32 electrodes, which in the long-term must be small enough to be implantable while also supporting wireless data and power reception. This system has been designed, and through serial data control, sends user-made neural signals to all 32 channels. Additionally, by consisting of only two chips, the product package can be made small enough for surgical implantation. It also supports both USB and RF signal data transfer, for current and future use, respectively. Provided the device is in working order, the implant will be able to target specific sections of spinal tissue based on associated muscular function, using patterned, tailored electrode stimulation. This will potentially make locomotion rehabilitation easier for test mice, and eventually for patients with complete spinal cord injuries.

Reinventing the Wheel: Development of a Collapsible Wheel for the Axel Rover

Christine L. Fuller

Mentors: Joel Burdick and Issa Nesnas

The Axel rover is a proposed solution to negotiating extreme terrain currently inaccessible to conventional rovers. Axel consists of a cylindrical body, cantilever arm, trailing tether, and two paddle wheels. It depends on a host rover to accommodate it during launch and as a tether anchor. To be feasible, Axel must be small, light, and minimally invasive. Accordingly, we are developing wheels to collapse during launch and expand on deployment. The wheel-terrain interactions that govern the rover's mobility are determined by tradeoffs. Paddles on the end of the wheel enable the rover to surmount obstacles 70-80% of the wheel diameter but are inefficient on smooth ground. Complex mechanisms allow optimization to the terrain but may introduce more points of error. Thicker beams are stronger but heavier. In this paper, I present our analysis of design tradeoffs, functional prototypes, and results from testing in the JPL Mars Yard.

Optimization of Velocity Interferometer for Any Reflecting Surface (VISAR)

Keir Gonyea

Mentor: Guruswami Ravichandran

The VISAR is necessary for velocity readings during impact experiments. The lab's VISAR produced unusable data because the noise and fringing (actual data) had comparable signal amplitudes. This paper is concerned with the reduction of noise in the VISAR signals and optimization of fringing along with producing code for data reduction and controlling the phase shifts (quadrature) in the two sin wave signals. Noise was never fully solved, but optimizing the fiber optic connections and light level helped reduce it. The fringes were optimized by introducing a cube beam splitter to change to a wide angle set-up and ensure exact path lengths. Quadrature control was attained by placing the $\frac{1}{4}$ wave plate in a rotational stage. With the afore mentioned improvements, the signals were clean enough to produce

accurate and usable data. Validation tests have been run with aluminum that confirm the data produced by the VISAR.

Campus Water Uses and Potential Water Efficiencies

Calvin Kuo

Mentor: Melany Hunt

With recent increases in the price of water, saving water has become one of the main focuses for sustainability. The California Institute of Technology used 200,000,000 gallons of water in the year 2008, however CalTech has never tracked this water to its destination within the campus. Using data collected from water meters on campus and from the utility company that supplies the campus with water, this research has produced a model that details how the water is distributed throughout campus. With this information, CalTech can then identify the heaviest water users and implement measures that will reduce the water consumption on campus.

Carbon Emissions Modeling of Caltech

Edward Lee

Mentor: Melany Hunt

It is no surprise that given the current state of the economy as well as the growing concern of carbon emissions and global warming, it is imperative for Caltech to model its own emissions and learn how to conserve energy. The first step for the Caltech community is to build a model that accurately determines our emissions as well as our projected emissions for the following years. Last year, this project began using the Clean Air Cool Planet carbon emissions model, a model built specifically for the representation of a college or university's emissions. It is important now, to collect more data as well as add aspects to the model where assumptions were previously made such as embedded carbon in water transport, air travel, and the use of refrigerants and chemicals. Current results show that Caltech's emissions have started to level off with the 2008 emissions roughly the same as the 2007 emissions at around 90,000 MT of eCO₂. Caltech's next step will be to look for places to cut back its use and ultimately lower its carbon footprint, an imperative goal with the many carbon emissions reduction plans currently enforced.

Developing a Miniature Robotic Neural Recording Micro-Drive

Ga-Il Lee

Mentor: Joel W. Burdick

This paper describes a prototype Miniature Robotic Neural Recording Micro-Drive (MRNRMD), which can autonomously position electrodes with micron precision and semi-chronically record neural signals (action potentials). The prototype is part of the ultimate goal, which is to create a fully autonomous and chronic neural implant device- a "smart" NRMD that can one day allow patients with lost motor functions to regain the control over their physical environment solely by their thoughts. The prototype presented was constructed by 3D-printing technology and made bio-compatible through Parylene coating. This third generation of NRMD greatly improves the functionality of previous models so that it can improve the procedures and results of the experimentalists in neurophysiology and neural prosthetics.

Microprocessor System to Stimulate/Record a High Density Electrode Array

Nitin Sharma

Mentor: Joel Burdick

The goal of the overall research project is to rehabilitate patients with 'complete spinal cord injuries'. To regenerate the lost motor skills, we stimulate electric signals on the specific segments of the spinal cord using a 32 high-density electrode array, and record the response. The aim of this project is to build a microprocessor system capable of simulating/recording 32 channels simultaneously. This project also includes various short term goals to improve the usability of the current commercially available system that can stimulate/record 8 channels. A control interface has been built to control the system from the distance, and a multiplexing circuit has been built to extend the functionality of the system to 32 channels.

In-Situ Instruments for Extreme Environments

John A. Ulvestad

Mentors: Albert Behar and Jaret Matthews

The Greenland Moulin Explorer project will study Moulin's, narrow tubular chutes through which surface-melt drains to the glacial bed. Mission objectives include developing a rugged probe to study glacial dynamics. This lightweight, inexpensive tethered device is intended to float in the water and be easily carried by the current into the glacier. Video will be sent to the surface in real-time through a one-kilometer-long Falmat fiber-optic cable. Using a Modular Signal Recorder, data will be gathered on

temperature, humidity, pressure, and acceleration. The data received will be used to analyze the rate of reduction of Greenland's ice sheet. The Antarctic Ice Borehole Probe mission is a geological investigation to study the ice structure under the Antarctic Ice Shelf. The objectives of the mission are to observe the ice sheet processes using newly upgraded high-resolution Sony cameras and high-brightness LEDs. Camera controls are sent to the probe via fiber-optic cable, and real-time video is received at the surface. Information gathered will aid the exploration of ice and water environments on Earth and other planets. Expertise gained in both these projects will assist in the development of technology to acquire data in extreme environments.